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**OAK RIDGE NATIONAL LABORATORY**

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POST OFFICE BOX X, OAK RIDGE, TENNESSEE 37831


ORNL/RAP/LTR-86/71

#1044 (add)

DATE: September 30, 1986

SUBJECT: Preliminary Assessment of the Radiological Impact for Individual Waste Management Areas at the Oak Ridge National Laboratory: Status Report

TO: T. E. Myrick

FROM: M. B. Sears

#1044 (add)



UCN-2383K
(3 8-84)

MARTIN MARIETTA

# Internal Correspondence

F: Proj. Strat. Dev. Prelim. Dose Estimate

MARTIN MARIETTA ENERGY SYSTEMS, INC.

E-mail
Pg. 14 LLW line not PW at 3074.
JOC/RMB/TRA

September 30, 1986

T. E. Myrick, 3047, MS 329 (4-6332)

Preliminary Dose Estimates from Individual Sites (MS 6.12)

Attached is the draft report for the subject task. Copies have been forwarded to John Trabalka, Leroy Stratton, Johnnie Cannon, Rich McLean, Don Lee, and John Witherspoon for review and comment. If you would like for others to review the report, please let me know. I plan to finalize the report in another week or so after receipt of comments and suggestions.

Mildred Sears / MGW
M. B. Sears, 4500N, MS 233 (4-6300)

MBS:mgw

Attachment

cc: J. B. Cannon, 4500N, MS D33 (4-4541)
D. W. Lee, 2001, MS 002 (4-5803)
R. B. McLean, 4500N, MS D33 (4-7383)
L. E. Stratton, 3504, MS 25 (6-0504)
J. R. Trabalka, 1505, MS 2 (4-7382)
J. P. Witherspoon, 7509 (6-2105)

**DRAFT**

Letter Report RAP86-71
(Internal Distribution Only)
9.24.86

# PRELIMINARY ASSESSMENT OF THE RADIOLOGICAL IMPACT FOR INDIVIDUAL WASTE MANAGEMENT AREAS AT THE OAK RIDGE NATIONAL LABORATORY: STATUS REPORT

M. B. Sears

Fuel Recycle Division

September 1986

Prepared by the
OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37831
operated by
MARTIN MARIETTA ENERGY SYSTEMS, INC.
for the
U.S. DEPARTMENT OF ENERGY
under
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# ABSTRACT

A study was made (1) to estimate the radiological impact (i.e. the doses) for individual waste management areas at the Oak Ridge National Laboratory and (2) to rank the areas for remedial action based on the off-site doses which result from discharges to surface streams. Some data was found for $^{90}Sr$, but quantitative source term data for individual sites was not found for $^{3}H$, $^{137}Cs$, or $^{60}Co$. A qualitative assessment was made and areas were ranked for remedial investigation based on the available information.

# 1. INTRODUCTION AND SUMMARY

Current operations and residual effects from past activities at the Oak Ridge National Laboratory (ORNL) result in discharges/leaks of radioactive materials to the environment. Because of new regulatory requirements, it is necessary to assess the effectiveness of the ORNL waste disposal units, and the need for corrective action.

The objectives of this subtask under the remedial action program are (1) to estimate the radiological impact (i.e. the doses) for the individual waste management sites or areas, and (2) to rank the sites for remedial action based on the doses. The scope of the initial phase is the off-site dose to the general public which results from current releases/leaks to surface streams in the White Oak Creek watershed.

The nuclides which are important as source terms were defined based on dose calculations for the total discharges measured at White Oak Dam. For drinking the water at White Oak Dam, the major contributors to the effective total-body dose are $^{3}H$ ($\sim$70% and $\sim$50% for 1984 and 1985 respectively) and $^{90}Sr$. The 1985 releases were not typical because (1) two $^{90}Sr$ spills occurred and (2) the precipitation was substantially below normal, which reduced seepage from the solid waste storage areas (SWSAs). For eating fish caught in the Clinch River near the confluence with White Oak Creek, $^{137}Cs$ contributes 60% to 90% of the effective total-body dose (varies with species) and $^{90}Sr$ most of the remainder. Strontium-90 is the major contributor to the bone dose (the maximum organ dose) via either pathway. Cobalt-60 is a relatively minor contributor to the off-site dose. Although not a part of this study, the $^{60}Co$ in the contaminated creek gravels is a major source of ground surface exposure to personnel in the contaminated creek areas.

A search was made for data concerning releases from the individual waste management sites. Some information has been found for $^{90}Sr$, although it is primarily by area, rather than for individual sites. Quantitative source term data for individual sites or areas has not been found for $^{3}H$, $^{137}Cs$, or $^{60}Co$. Additional source term data is needed before the dose calculations can be made.

A qualitative assessment was made based on the available information. Of the discharges which are known, the areas which are the largest active sources of the environmentally significant radionuclides, and hence offer the greatest potential for dose reduction (near term) if corrective measures are applied, are as follows:

1a. Central ORNL site in Bethel Valley

1b. SWSA 5

2a. SWSA 4

2b. Process waste treatment plant.

From the long-range perspective it is important to establish that the long-lived transuranic (TRU) alpha emitters are not migrating and will be permanently confined in the burial grounds.

This study does not address decommissioning/closure, the intruder, or worker exposure.

# 2. BACKGROUND

The Oak Ridge National Laboratory (ORNL) is a large multipurpose research laboratory whose basic mission is the discovery of new knowledge, both basic and applied, in all areas related to energy. The Laboratory's facilities consist of nuclear reactors, chemical pilot plants, research laboratories, radioisotope production laboratories and support facilities. The central ORNL site and most satellite areas including the burial grounds lie in the White Oak Creek (WOC) watershed, which is a small tributary of the Clinch River. The WOC watershed has received treated and untreated effluents from Laboratory activities since 1943. Controlled releases include those from the process waste treatment plant (PWTP), the sewage treatment plant (STP), and a variety of process waste holdup ponds scattered throughout the ORNL complex. The WOC also receives discharges from nonpoint sources such as solid waste storage areas (SWSAs), the liquid waste seepage pits and trenches area (closed in the mid 60's), leaking ponds, leaking transfer pipes, contaminated pipe trenches, and other sources which have been contaminated by leaks and spills over the years.

A brief description of the existing environment is presented here to enhance understanding of the surface water transport pathways. Much of the material contained in Sect. 2.1 (Surface Stream Description and Use) and Sect. 2.2 (Groundwater Description and Use) were taken from the environmental analyses by Boyle et al. and the site data compilation by Fitzpatrick.[1,2] These reports should be consulted for more detailed information and a complete listing of reference sources.

## 2.1 Surface Stream Description and Use[1]

White Oak Creek drains an area of 17 $km^2$ in Bethel and Melton Valleys (Fig. 2.1). It originates on the forested slopes of Chestnut Ridge; the mouth is at Clinch River kilometer (CRK) 33.5. The Clinch is part of the Tennessee River watershed and is controlled by the operation of Tennessee Valley Authority dams.

After leaving Chestnut Ridge, WOC flows southwest through Bethel Valley and the central ORNL site. These areas are underlain by the Knox dolomite and Chickamauga limestone respectively which are water bearing formations. Discharge from the Knox is the main source of the base flow. The creek then passes through a gap in Haw Ridge (Rome formation) and enters Melton Valley, which is underlain by the Conasauga shale. These formations contribute little to the creek's base flow. Flow rates vary from a maximum of 18.2 $m^3/s$ to a minimum of zero, the average being 0.27 $m^3/s$.[1] The ORNL plant discharges substantially augment the dry weather flow.

After passing Haw Ridge, WOC is joined by its major tributary, Melton Branch, which is the drainage basin of the ORNL facilities in Melton Valley. Flow rates vary from a maximum of 6.85 $m^3/s$ to zero, averaging 0.07 $m^3/s$.[1]

The waters of WOC and its tributaries are impounded by a dam 1 km above its mouth. White Oak Lake is a small shallow impoundment that functions as the final settling basin for waste effluents. The normal lake level creates a pool surface area of approximately 9.8 ha (24 acres) with approximately a 2-d retention time. The structure has floodgates to allow temporary impoundment of flow in the event of an accidental spill. The discharge is monitored continuously for flow and water quality. The average flow in WOC at the dam is 0.38 $m^3/s$.[1]

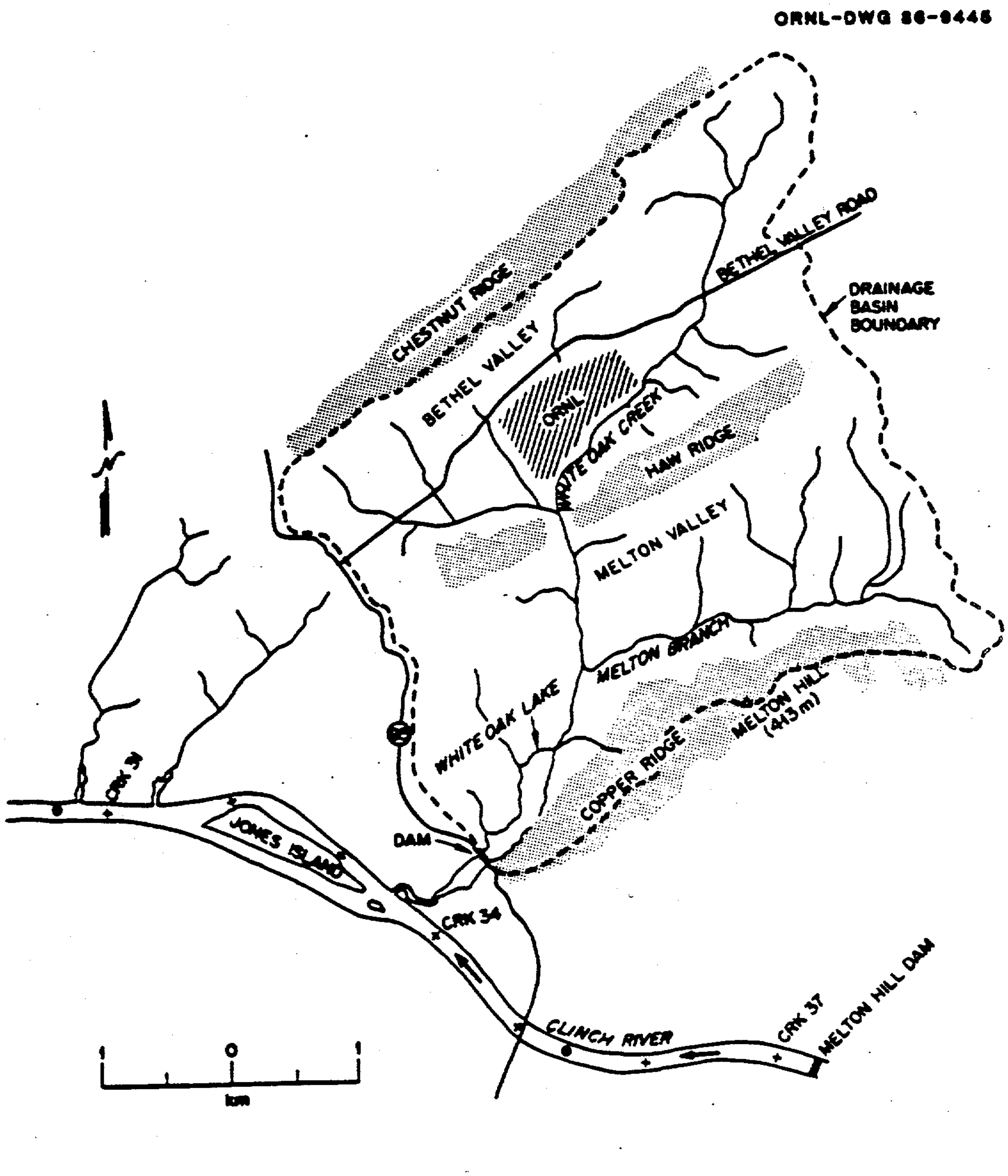


Fig. 2.1. White Oak Creek watershed.

Water levels and flow in the WOC embayment below White Oak Dam are largely controlled by the operation of Melton Hill Dam 3.7 km upstream on the Clinch River, and Watts Bar Dam about 94 km downstream on the Tennessee River. During summer months (mid-April through October), Watts Bar Reservoir's pool creates a backwater that extends upstream to White Oak Dam. During the winter months the embayment resembles a large mudflat. Power is not generated continuously at Melton Hill Dam, so water flow in the Clinch is pulsed. As a result, daily fluctuations in water levels and flow (including reversals) occur in White Oak Embayment.

The average Clinch River flow at Melton Hill Dam between 1969 and 1979 was 150 $m^3/s$.[1] The average summer (June to September) discharge was 134 $m^3/s$. Periods of no flow over the dam have lasted as long as 29 days; the average number of days per year of no flow is 13.

Major uses of surface water in the ORNL area include withdrawals for industrial and public supplies, navigation, and recreational activities such as fishing and swimming. There are several water withdrawals from surface sources for industrial and public water supplies within a 32.2-km radius of ORNL; the closest withdrawals downstream of the outfall of White Oak Dam are at the Oak Ridge Gaseous Diffusion Plant (CRK 23.3) and Kingston, located 10.4 km and 34.1 km from ORNL. The intake to the Kingston water filtration plant is located on the Tennessee River approximately one-half mile upstream from the confluence of the Clinch and Tennessee Rivers. Normally, Tennessee River water is used, but under certain conditions of power generation backflow can occur. Under backflow conditions, Clinch River water may move upstream in the Tennessee River and be used as the source of water for the Kingston filtration plant.

Recreational surface water uses include boating, fishing, waterskiing, and swimming. Two public boat docks are located in the vicinity of Melton

Hill Dam. Most swimming and waterskiing activity takes place above Melton Hill Dam at public facilities. No quantitative data are currently available on the number or amount of fish taken for human consumption from the tailwater area.

## 2.2 Groundwater Description and Use[1-3]

Base flow of the surface water of the WOC watershed is maintained primarily by groundwater discharge and the discharge of process streams from ORNL facilities. The nature and extent of an aquifer are determined by the character, distribution, and structure of the bedrock and the overlying soil, as well as by the size, shape, and continuity of the interstices.

Two regions of subsurface water are commonly distinguished: the zone of unsaturation (the weathered soil overlay or recharge zone) and the zone of saturation (the major water-containing area). The water table is defined as the upper surface of the zone of saturation.

The four major geologic zones of the ORNL area discussed earlier differ somewhat in their groundwater characteristics and capacity. Of the four groups, only the Knox Dolomite has any extensive water storage capacity. This storage usually occurs in solution cavities that may be quite large in some instances and may frequently result in springs, as seen in the headwaters of WOC. Water storage capacity of the Rome Formation, Conasauga Shale, and Chickamauga Limestone is small and occurs primarily along joints and bedding planes. Most wells in these formations typically have flows less than 10 gal/min.

Groundwater flow in the weathered residual soil on the ORNL site basically follows water table conditions; that is, groundwater levels parallel topographic contours moving from areas of high elevation to areas of low elevation. However, direction of movement in the underlying bedrock is influenced strongly by directional variations in permeability. In the Chickamauga Limestone underlying Bethel Valley, groundwater moves through small solution channels and is essentially a subdued replica of the topography. Studies of groundwater movement in the Conasauga Shale of Melton Valley have suggested that the primary direction of groundwater movement parallels the strike. Groundwater discharge is through evapotranspiration, springs, and streams; and it contributes to the base flow of surface streams that ultimately augment the Clinch River water supply. The bed of the Clinch River lies at the basal level of the zone of saturation, and groundwater from both sides of the channel enters the river. It is commonly believed that groundwater flow does not pass beneath the Clinch River except in cases where extensive well pumping may lower the water table.

Depth to the water table varies both spatially and temporally. At a given location, depth to water is generally greatest during the October-December quarter and least during the January-March quarter, corresponding to periods of minimum and maximum precipitation. In Bethel Valley, depth to the water table ranges from 0.3 to 11 m, whereas in Melton Valley the range is from 0.3 to 20 m.

Although the major portion of industrial and public drinking water supplies in the Oak Ridge area is taken from surface water sources, there are numerous single-family wells in adjacent rural areas. Of the domestic wells located within 16 km of ORNL (listed by the Tennessee Department of Conservation, Division of Water Resources), most are south of the Clinch River. Those north of the Clinch River in the north central portion of

Roane County are from 10 to 16 km distant from ORNL. There are four industrial and three public groundwater supplies within 16 km of ORNL. It is generally believed that there is a very low probability of groundwater migration from the reservation to offsite wells, particularly those south of the Clinch River and those upgradient from the site.

An extensive investigation of the groundwater characteristics involving the drilling of a number of additional monitoring wells is currently in progress.

## 2.3 Climatic Factors

Precipitation, the driving mechanism of the hydrologic system, is plentiful on the Oak Ridge Reservation. Precipitation establishes the quantity and variation in runoff and stream flow as well as replenishment to the groundwater system. These factors affect the leaching of burried wastes and the transport of contaminants from nonpoint sources to the creek as well as the transport of contaminated sediments in the creek and White Oak Lake.

The closest long-term meteorological data (1948 to present) is available from the National Oceanic and Atmospheric Administration (NOAA) weather station in Oak Ridge townsite, about 11 km from the central ORNL site in Bethel Valley and about 13 km from the Melton Valley burial grounds. The record mean annual precipitation at townsite is 138.8 cm (54.7 in.).[4] The winter months are characterized by passing storm fronts, and this is the period of highest rainfall. Winter storms are generally of low intensity and long duration. Another peak in rainfall occurs in July (or sometimes August) when short, heavy rains associated with thunderstorms are common. The annual precipitation for the period 1976 to 1985 and the long-term monthly mean precipitation at the NOAA station are given in Tables 2.1 and 2.2.

Table 2.1. Annual precipitation at NOAA Oak Ridge townsite station, 1976 - 1985[a]

| Year | Precipitation (cm) |
|---|---|
| 1976 | 135.5 |
| 1977 | 159.4 |
| 1978 | 123.0 |
| 1979 | 170.9 |
| 1980 | 101.9 |
| 1981 | 108.2 |
| 1982 | 152.5 |
| 1983 | 121.1 |
| 1984 | 143.6 |
| 1985 | 118.8 |
| Record mean | 138.8[b] |

[a]B. Hicks (NOAA), personal communication to M. B. Sears, June 4, 1986.
[b]Period of record, January 1948 - December 1984.

Table 2.2. Average monthly precipitation at NOAA Oak Ridge townsite station[a,b]

| Month | Precipitation (cm) |
|---|---|
| January | 13.39 |
| February | 12.04 |
| March | 15.06 |
| April | 10.92 |
| May | 11.20 |
| June | 10.29 |
| July | 13.67 |
| August | 9.37 |
| September | 9.12 |
| October | 7.77 |
| November | 11.92 |
| December | 14.12 |
| Total | 138.84 |

[a]B. Hicks (NOAA), personal communication to M. B. Sears, June 4, 1986.
[b]Period of record, January 1948 - December 1984.

Loss of water to the atmosphere by evapotranspiration is about 76 cm (30 in) annually or about 55% of the total annual precipitation.[5] Evapotranspiration is at a maximum from July to September, during the vegetation growing season. Seasonal relationships between evapotranspiration and precipitation are reflected in seasonal patterns of runoff to streams. Runoff is greatest in winter when evapotranspiration is low and precipitation is high. Precipitation not lost as evapotranspiration or quick runoff to streams percolates through the soil and eventually recharges the groundwater system.

## 2.4 References


1. J. W. Boyle, et al. Environmental Analysis of the Operations of the Oak Ridge National Laboratory (X-10 Site), ORNL-5870, November, 1982.

2. F. C. Fitzpatrick, Oak Ridge National Laboratory Site Data for Safety Analysis Reports, ORNL/ENG/TM-19, December, 1982, pp. 2-188 to 2-206.

3. C. E. Nix, F. K. Edwards, T. E. Myrick, J. R. Trabalka, and J. B. Cannon, CERLA Phase 1 Report: Identification and Preliminary Assessment of Inactive Hazardous Waste Disposal Sites and Other Contaminated Areas at ORNL, ORNL/TM-9989, March, 1986.

4. B. Hicks (NOAA), personal communication to M. B. Sears, June 4, 1986.

5. Environmental Surveillance of the Oak Ridge Reservation and Surrounding Environs During 1985, ORNL-6271, April, 1986, p. 16.

# 3. PRINCIPAL RADIONUCLIDES VIA WATER PATHWAY

Radionuclides were selected as source terms for this study based on the off-site doses which result from current releases at White Oak Dam. The annual radiological discharges to the Clinch River for the period 1976 to 1985 are presented in Table 3.1. There is some variation from year to year due in part to differences in precipitation which affects seepage from the burial grounds.

Doses for drinking the water were estimated based on measured concentrations at White Oak Dam in 1984 and 1985 (Table 3.2). The analysis assumes an intake of 730 L/year (2L/d) and the dose conversion factors given in Table 3.3. No one is known to drink the water at White Oak Dam. For the annual environmental monitoring reports, doses are calculated after dilution by the Clinch River.[1] After dilution (assuming complete mixing) the total body dose commitment for drinking Clinch River water at CRK 33.3 was about 0.15 mrem in 1984 and 1985. The dilution varies from year to year (Table 3.4). In 1984 and 1985 the ratio of Clinch River flow to White Oak Creek flow was about 300. The long-term average dilution is about 390 based on data by Boyle et al.[2] However, Table 3.2 illustrates the type of doses which might be expected if the regulations should change and the concentration factor were applied at White Oak Dam.

For drinking the water, the major contributors to the effective total body dose are $^{3}H$ (~70% and ~50% for 1984 and 1985 respectively), and $^{90}Sr$. Strontium-90 is the major contributor to the bone (endosteal cells) dose (the maximum organ dose). The year 1984 was the closest to average precipitation of recent years and operating releases were relatively stable. The 1985 releases were not typical because (1) the break in the process waste line servicing building 3074 and the spill from the

LLW line

Table 3.1. Annual releases of radionuclides from White Oak Creek to the Clinch River

| Year | Releases (Ci) | | | | | | |
|---|---|---|---|---|---|---|---|
| | $^{3}H$ | $^{60}Co$ | $^{90}Sr$ | $^{106}Ru$ | $^{131}I$ | $^{137}Cs$ | TRU |
| 1976[a] | 7420 | 0.9 | 5[b] | 0.2 | 0.03 | 0.2 | 0.01 |
| 1977[a] | 6250 | 0.4 | 3 | 0.2 | 0.03 | 0.2 | 0.03 |
| 1978[a] | 6290 | 0.4 | 2 | 0.02 | 0.04 | 0.07 | 0.03 |
| 1979[c] | 7700 | 0.9 | 2.44 | 0.13 | 0.06 | 0.24 | 0.03 |
| 1980[d] | 3400 | 1.4 | 1.4 | <0.01 | 0.09 | 0.60 | 0.040 |
| 1981[d] | 2900 | 0.66 | 1.5 | 0.1[e] | 0.04 | 0.23 | 0.043 |
| 1982[d] | 5400 | 0.96 | 2.7 | 0.2[e] | 0.06 | 1.5 | 0.034 |
| 1983[d] | 5600 | 0.29 | 2.1 | 0.18 | 0.004 | 1.2 | 0.048 |
| 1984[d] | 6400 | 0.17 | 2.6 | 0.28 | 0.057 | 0.56 | 0.028 |
| 1985[f] | 3700 | 0.62 | 3.0 | 0.01 | NA[g] | 0.42 | 0.008 |

[a]T. W. Oakes and K. E. Shank, Radioactive Waste Disposal Areas and Associated Environmental Surveillance Data at Oak Ridge National Laboratory, ORNL/TM-6893, December 1983, p. 14.

[b]New process waste treatment plant became operational April, 1976. (T. W. Oakes and K. E. Shank, Radioactive Waste Disposal Areas and Associated Environmental Surveillance Data at Oak Ridge National Laboratory, ORNL/TM-6893, December, 1979, p.25.)

[c]Environmental Monitoring Report, United States Department of Energy, Oak Ridge Facilities, Calender Year 1979, Y/UB-13 June 2, 1980, p. 36.

[d]Environmental Monitoring Report, United States Department of Energy, Oak Ridge Facilities, Calender Year 1984, ORNL-6209, August 1985, p.26.

[e]W. F. Ohnesorge, Historical Releases of Radioactivity to the Environment from ORNL, ORNL/M-135, May 1986, p. 19.

[f]Environmental Surveillance of the Oak Ridge Reservation and Surrounding Environs During 1985, ORNL-6271, April 1986, p. XXIV.

[g]NA = not available.

Table 3.2. Doses from drinking water at White Oak Dam[a]

| Radionuclide | Average concentration in water[c,d] (uCi/ml) | Individual Dose (mrem)[b] Effective total-body[e] | | Individual Dose (mrem)[b] Bone[f] |
|---|---|---|---|---|
| | | **1984** | | |
| $^{3}H$ | 4.8 E-4 | 31.5 | (70%) | 23.0 |
| $^{60}Co$ | <1.08 E-8 | 0.1 | | 0.03 |
| $^{90}Sr$ | 1.7 E-7 | 10.9 | (25%) | 106.7 (81%) |
| $^{106}Ru$ | 1.8 E-8[g] | 0.4 | | 0.1 |
| $^{131}I$ | 3.7 E-9[g] | 0.2 | | <0.01 |
| $^{137}Cs$ | 2.9 E-8 | 1.7 | | 1.7 |
| | Total | 44.8 | | 132 |
| | | **1985** | | |
| $^{3}H$ | 3.5 E-4 | 22.9 | (51%) | 16.8 |
| $^{60}Co$ | 6.3 E-8 | 0.5 | | 0.2 |
| $^{90}Sr$ | 3.0 E-7 | 19.2 | (43%) | 188.3 (91%) |
| $^{106}Ru$ | 1.0 E-9[g] | 0.02 | | <0.01 |
| $^{137}Cs$ | 4.2 E-8 | 2.5 | | 2.5 |
| | Total | 45.1 | | 208 |

[a]No one is known to drink the water at White Oak Dam.

[b]Fifty-year dose commitment. Intake of water, 730 L per year.

[c]Environmental Surveillance of the Oak Ridge Reservation and Surrounding Environs During 1985, ORNL-6271, April 1986, p. 123.

[d]Environmental Monitoring Report, United States Department of Energy, Oak Ridge Facilities, Calendar Year 1984, ORNL-6209, August 1985, p.23.

[e]Weighted sum dose.

[f]Endosteal cells of the bone.

[g]Estimated from total releases.

Table 3.3. Fifty-year committed dose equivalent conversion factors used for drinking water calculations[a]

| | | Ingestion doses (rem/uCi) | |
|---|---|---|---|
| Nuclide | F1 | Effective dose commitment | Endosteal |
| $^{3}H$ | 9.50E-01 | 8.98E-05 | 6.56E-05 |
| $^{60}Co$ | 5.00E-02 | 1.13E-02 | 3.99E-03 |
| $^{90}Sr$ | 2.00E-01 | 8.75E-02 | 0.86 |
| $^{106}Ru$ | 4.00E-02 | 2.88E-02 | 9.57E-03 |
| $^{131}I$ | 9.5E-01 | 5.45E-02 | 3.32E-04 |
| $^{137}Cs$ | 9.50E-01 | 8.19E-02 | 7.99E-02 |

[a]D. E. Dunning, Jr., G. G. Killough, S. R. Bernard, J. C. Pleasant, P. J. Walsh, Estimates of Internal Dose Equivalent to 22 Target Organs for Radionuclides Occurring in Routine Releases from Fuel Cycle Facilities, Vol. III; NUREG/CR-0150, Vol. 3, Oct. 1981, pp. 59-62, 81.

Table 3.4. Dilution of White Oak Creek flow by the Clinch River

| Year | Average dilution factor[a] |
|---|---|
| 1979 | 511[b] |
| 1980 | 1130[c] |
| 1981 | 371[d] |
| 1982 | 463[e] |
| 1983 | NA[f] |
| 1984 | 310[g] |
| 1985 | 290[h] |

[a]Ratio of Clinch River to White Oak Creek flow.

[b]Environmental Monitoring Report United States Department of Energy Oak Ridge Facilities Calendar Year 1979, Y/UB-13, June 1980, p. 10.

[c]Environmental Monitoring Report United States Department of Energy Oak Ridge Facilities Calendar Year 1980, Y/UB-15, June 10, 1981, p.9.

[d]Environmental Monitoring Report United States Department of Energy Oak Ridge Facilities Calendar Year 1981, Y/UB-16, May 1, 1982, p.10.

[e]Environmental Monitoring Report United States Department of Energy Oak Ridge Facilities Calendar Year 1982, Y/UB-18, May 1, 1983, p. 10.

[f]NA = not available.

[g]Environmental Monitoring Report United States Department of Energy Oak Ridge Facilities Calendar Year 1984, ORNL-6209, August 1983, p. 100.

[h]Estimated from Environmental Surveillance of the Oak Ridge Reservation and Surrounding Environs During 1985, ORNL-6271, April 1986, p. 127.

ventilation filter pit near building 3517 resulted in higher than normal $^{90}Sr$ releases from the central ORNL complex and (2) the precipitation was below normal which reduced seepage from the burial grounds (see Sect. 3).

Fish are collected from the Clinch River and analyzed. The calculated 1985 doses from eating fish assuming the ingestion of 20 kg of fish flesh in a year are given in Table 3.5. The highest doses are for eating fish caught at Clinch River kilometer (CRK) 33.3 (the confluence with White Oak Creek). The dose conversion factors used for fish calculations are listed in Table 3.6. Individuals have been known to consume carp patties prepared by grinding fish flesh and bone. Consumption of 10 kg of fish patties containing the maximum amount of $^{90}Sr$ (carp caught near the confluence with White Oak Creek) would result in an effective total body dose equivalent of 0.6 mrem and a dose to the bone (endosteal cells) of 6 mrem.[3] This is based on the assumption that 10% of the carp patty is bone.[3]

For eating fish caught in the Clinch River near the confluence with White Oak Creek, $^{137}Cs$ contributes 60% to 90% of the effective total body dose (varies with species) and $^{90}Sr$ most of the remainder. Strontium-90 is the major contributor to the bone dose and the doses from eating carp patties.

In summary, the nuclides which are important as source terms via the water pathway for off-site dose calculations are $^{3}H$, $^{90}Sr$, and $^{137}Cs$. The $^{60}Co$ in the creek sediments/gravels is of concern because with its high gamma it is the major contributor to the ground surface exposure of personnel in the creek area.[1] From the long range perspective it is important to establish that the long-lived transuranic alpha emitting nuclides are not migrating and will be permanently confined in the burial grounds.

Table 3.5. Doses from consumption of Clinch River fish[a,b]

| Location | Fish Species | $^{60}Co$ | $^{90}Sr$ | $^{137}Cs$ | $^{234}U$ | $^{235}U$ | $^{238}U$ | $^{238}Pu$ | $^{239}Pu$ | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Effective total-body dose[c] (mrem) | | | | | | | | |
| Clinch River km 40.0[d] | | | | | | | | | | |
| | Bass | 0.0 | 0.0029 | 0.013 | 0.0035 | 0.00018 | 0.0021 | 0.000079 | 0.000079 | 0.022 |
| | Bluegill | 0.0 | 0.0037 | 0.022 | 0.011 | 0.0012 | 0.0049 | 0.00015 | 0.000097 | 0.043 |
| | Carp | 0.0 | 0.029 | 0.012 | 0.0091 | 0.0020 | 0.0041 | 0.000055 | 0.000018 | 0.056 |
| Clinch River km 33.3[e] | | | | | | | | | | |
| | Bass | <0.0053 | 0.13 | 1.2 | 0.0068 | 0.0012 | 0.0024 | 0.000095 | 0.000044 | 1.3 |
| | Bluegill | 0.0075 | 0.34 | 0.64 | 0.015 | 0.0019 | 0.0056 | 0.000095 | 0.00014 | 1.0 |
| | Carp | <0.0033 | 0.13 | 0.22 | 0.005 | 0.00075 | 0.003 | 0.000071 | 0.00061 | 0.36 |
| Clinch River km 19.2 | | | | | | | | | | |
| | Bass | <0.0015 | 0.014 | 0.1 | 0.0056 | 0.00069 | 0.0034 | <0.000063 | <0.000062 | 0.13 |
| | Bluegill | <0.0035 | 0.051 | 0.037 | 0.029 | 0.0026 | 0.014 | <0.00017 | 0.00047 | 0.14 |
| | Carp | <0.0017 | 0.037 | 0.029 | 0.018 | 0.0015 | 0.013 | 0.0001 | 0.00047 | 0.1 |
| Clinch River km 16.0 | | | | | | | | | | |
| | Bass | <0.0011 | 0.013 | 0.13 | 0.0043 | 0.00051 | 0.0035 | 0.0021 | 0.00039 | 0.16 |
| | Bluegill | 0.0044 | 0.027 | 0.069 | 0.011 | 0.00064 | 0.0056 | 0.0011 | 0.00033 | 0.12 |
| | Carp | 0.017 | 0.063 | 0.019 | 0.0079 | 0.0008 | 0.0038 | 0.00034 | 0.00015 | 0.11 |
| Clinch River km 8.0 | | | | | | | | | | |
| | Bass | <0.00086 | 0.013 | 0.099 | 0.0056 | 0.0011 | 0.0028 | 0.0017 | 0.00073 | 0.12 |
| | Bluegill | <0.0025 | 0.068 | 0.042 | 0.0096 | 0.00069 | 0.0082 | 0.00013 | 0.00063 | 0.13 |
| | Carp | <0.00075 | 0.077 | 0.047 | 0.0079 | 0.00085 | 0.0061 | 0.00037 | 0.000071 | 0.14 |
| Clinch River km 3.2 | | | | | | | | | | |
| | Bass | <0.0010 | 0.00088 | 0.046 | 0.0036 | 0.00075 | 0.0019 | 0.000032 | 0.00078 | 0.055 |
| | Bluegill | <0.0026 | 0.088 | 0.034 | 0.012 | 0.0020 | 0.0061 | 0.00020 | 0.000097 | 0.15 |
| | Carp | <0.00097 | 0.0071 | 0.055 | 0.0056 | 0.00040 | 0.0033 | 0.00051 | 0.000062 | 0.073 |

[a]Environmental Surveillance of the Oak Ridge Reservation and Surrounding Environs During 1985, ORNL-6271, April 1986, pp. 62,63.
[b]Fifty-year dose commitment, intake of fish, 20 kg/year.
[c]Weighted sum dose.
[d]Melton Hill Lake, i.e. background.
[e]Confluence with White Oak Creek.

Table 3.6. Fifty-year committed dose equivalent conversion factors used for fish calculations[a]

| Nuclide | Effective dose commitment (mrem/p Ci ingested) |
|---|---|
| $^{60}Co$ | 2.7 E-5 |
| $^{90}Sr$ | 1.4 E-4 |
| $^{137}Cs$ | 5.0 E-5 |
| $^{234}U$ | 2.8 E-4 |
| $^{235}U$ | 2.7 E-4 |
| $^{238}U$ | 2.5 E-4 |
| $^{238}Pu$ | 4.0 E-3 |
| $^{239}Pu$ | 4.4 E-3 |

[a]G. G. Killough and K. F. Echerman, Radiological Assessment, NUREG/CR-3332, 1983.

## 3.1 References


1. K. L. Daniels (ORNL), personal communication to M. B. Sears, June 23, 1986.

2. J. W. Boyle, et al., Environmental Analysis of the Operation of Oak Ridge National Laboratory (X-10 Site), ORNL-5870, November 1982, pp. 3-19, 3-20.

3. Environmental Surveillance of the Oak Ridge Reservation and Surrounding Environs During 1985, ORNL-6271, April 1986, p. 63.

# 4. RADIONUCLIDE RELEASES FROM VARIOUS WASTE AREAS TO WHITE OAK CREEK

## 4.1. Strontium-90

Water quality monitoring for $^{90}Sr$ has been conducted routinely at several stations on White Oak Creek and Melton Branch since 1979. These sampling stations are listed in Table 4.1 and the locations are shown on Fig. 4.1.

The average monthly $^{90}Sr$ releases (averaged over the year) from various waste areas to the White Oak Creek drainage are presented in Table 4.2 for the years 1979 to 1985. Also included in Table 4.2 is the average for the period 1979 to 1984. The average precipitation for this period at the NOAA Oak Ridge weather station was 133 cm per year compared with the record mean of 139 cm.[1] The 1985 releases were not typical because of two incidents, and below normal precipitation (119 cm), and therefore were not included in the averaging.

Of the discharges which are known, there is a "chronic" $^{90}Sr$ release of about 2.2 Ci per year averaged over the period 1979-1984 (Table 4.3). The principal contributors are undefined Bethel Valley sources, 31%; SWSA 4, 31%; and SWSA 5, 24%. No quantitative data is available for SWSA 6 or for underground pathways if any which might bypass the stream monitoring stations.

### 4.1.1 Construction activities and unplanned events

In 1985 there were two incidents and $^{90}Sr$ releases from undefined Bethel Valley sources were about 4 times the chronic releases, while inflow to the sewage treatment plant was double the norm. In 1982 releases were

Table 4.1. Listing of surface water monitoring stations monitored routinely for $^{90}Sr$, 1979-1985

| Location | Station code (see Fig. 4.1) |
|---|---|
| Flume on White Oak Creek near 190 Ponds | Flume |
| 190 Ponds (also called 3539 and 3540 ponds); holdup and monitoring ponds for 4500 area | 190 Ponds |
| Process waste treatment plant | PWTP |
| Sewage treatment plant | STP |
| 7500 bridge; the exit from Bethel Valley | 7500B |
| White Oak Creek just above confluence with Melton Branch | WOC |
| Melton Branch just above confluence with White Oak Creek | MB1 |
| Tributary to 7500 area [Homogeneous Reactor Test (HRT), Nuclear Safety Pilot Plant (NSPP), and Molten Salt Reactor Experiment (MSRE)] | HRT |
| Upper Melton Branch to 7900 area [High Flux Isotope Reactor (HFIR) and Transuranium Processing Plant (TRU)] | MB2 |
| Liquid waste pit disposal area (closed) | |
| East weir | East weir |
| West weir | West weir |

ORNL-DWG 81-21824R4

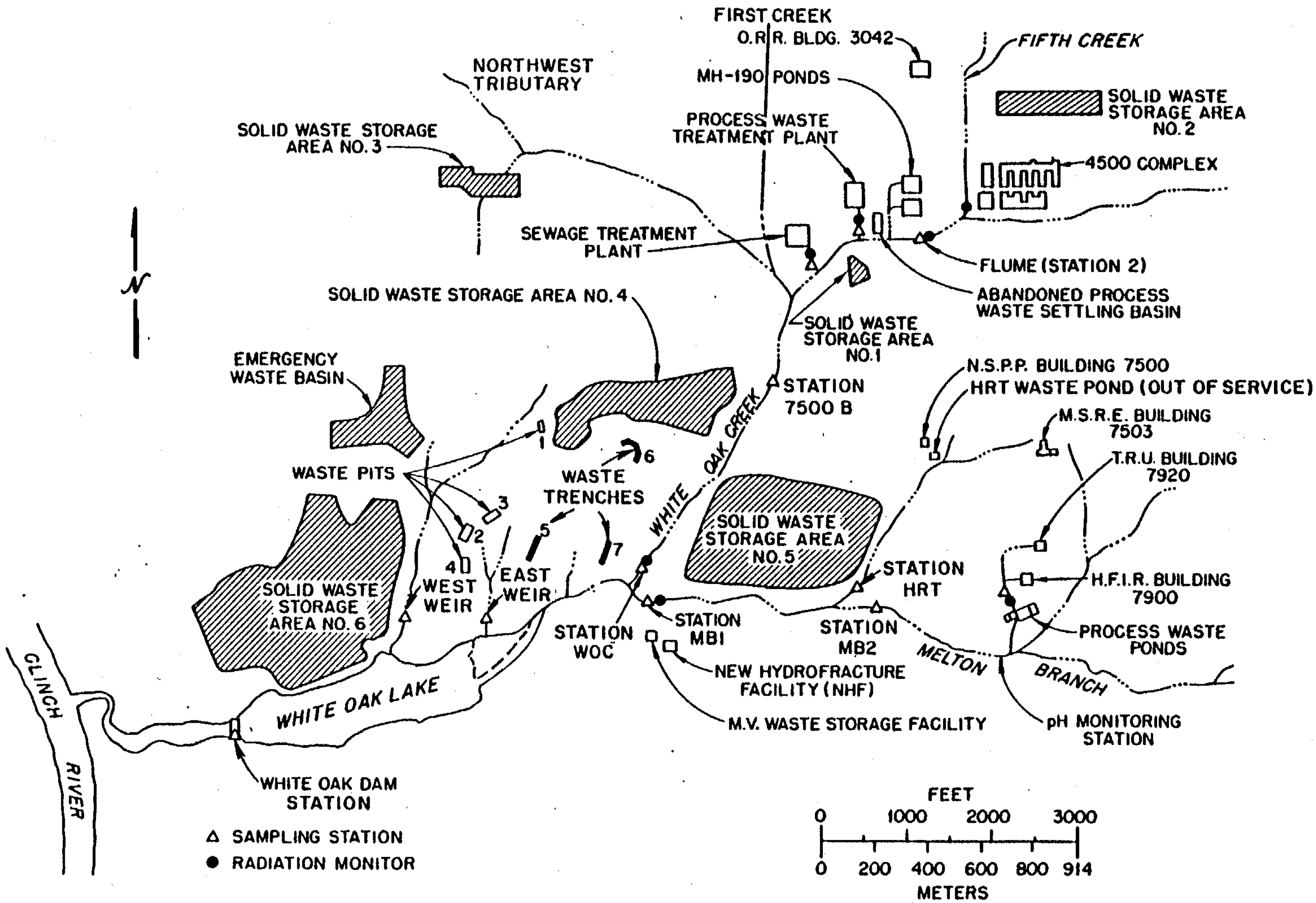


Fig. 4.1. Location map of ORNL waste facilities and sampling stations on White Oak Creek and Melton Branch.

Table 4.2. Average monthly contribution of $^{90}Sr$ from various ORNL areas[a,b] 1979-1985

| Area | Discharge (mCi/mo) 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | Chronic releases (Average 1979-1984) | 1985[c] |
|---|---|---|---|---|---|---|---|---|
| | | | | Measured contributors | | | | |
| Measured flume | 15 | 10 | 13 | 12 | 10 | 7.8 | 11 | 30 |
| Measured 190 Ponds | 1.0 | 2.4 | 0.40 | 0.20 | 0.20 | 0.40 | 0.8 | 1.1 |
| Measured Process Waste Treatment Plant (PWTP) | 2.9 | 1.9 | 2.7 | 0.50 | 0.30 | 0.40 | 1.4 | 2.8 |
| Measured Sewage Treatment Plant (STP) | 11 | 15 | 18 | 36 | 20 | 12 | 15[d] | 34 |
| (Sum) ORNL operations | 15 | 19 | 21 | 37 | 21 | 13 | 17 | 38 |
| Measured station 7500B | 70 | 77 | 72 | 115 | 85 | 72 | NA[e] | 253 |
| Measured station WOC | 170 | 110 | 100 | 180 | 170 | 110 | NA | 214 |
| Measured HFIR/TRU | 0.20 | 0.20 | 0.30 | 0.90 | 6.1 | 0.49 | 0.4[f] | 0.24 |
| Measured HRT/NSPP/MSRE | 6.6 | 4.8 | 3.3 | 9.0 | 4.9 | 5.2 | 5.6 | 4.7 |
| (Sum) Melton Branch facilities | 6.8 | 5.0 | 3.6 | 9.9 | 11 | 5.7 | 6.0 | 4.9 |
| Measured station MB1 | 67 | 52 | 17 | 50 | 82 | 44 | NA | 32 |
| Measured east weir | NA | 0.30 | 1.0 | 0.10 | 0.10 | 0.14 | 0.3 | 0.08 |
| Measured west weir | NA | 5.9 | 1.0 | 3.1 | 3.6 | 5.1 | 3.7 | 2.1 |
| (Sum) total pits | | 6.2 | 2.0 | 3.2 | 3.7 | 5.2 | 4.1 | 2.2 |
| Total effluents[g] (sum of Station WOC, Station MB1, and pits) | 240 | 170 | 120 | 230 | 260 | 160 | NA | 248 |
| Measured White Oak Dam Station | 200 | 125 | 123 | 225 | 208 | 216 | NA | 250 |
| | | | | Inferred contributors | | | | |
| Unidentified Bethel Valley sources [7500B minus (flume and ORNL operation)] | 40 | 48 | 38 | 66 | 54 | 51 | 46[d] | 185 |
| SWSA 4 (WOC minus 7500B) | 99 | 31 | 31 | 63 | 85 | 38 | 58 | h |
| SWSA 5 [MB1 minus (HRT and HFIR/TRU)] | 60 | 47 | 14 | 40 | 71 | 38 | 45 | 27 |

[a]Does not include underground pathways, if any, which might bypass the stream monitoring stations.
[b]Derived from data in Environmental Surveillance of the Oak Ridge Reservation and Surrounding Environs During 1985, ORNL-6271, April 1986, pp. 128, 129.
[c]Based on unpublished data in Department of Environmental Management (DEM) files; K. L. Daniels (ORNL), personal communications to M. B. Sears, June 23 and 26, 1986. The 1985 data in reference b apparently were preliminary results.
[d]Does not include 1982.
[e]NA = not applicable or not available.
[f]Does not include 1983.
[g]Does not include SWSA 6.
[h]In 1985 the input at the 7500 bridge station exceded the outflow at the WOC station.

Table 4.3. Annual contribution of $^{90}Sr$ from various waste areas to White Oak Creek drainage[a]

| Area | $^{90}Sr$ discharge (mCi/year) Chronic releases[b] (Average 1979-1984) | 1985[c] |
|---|---|---|
| Bethel Valley | | |
| Process waste treatment plant | 17 | 33 |
| Sewage treatment plant | 180[d] | 400 |
| 190 Ponds | 10 | 13 |
| Undefined sources | | |
| Upstream of flume | 130 (6%) | 360 |
| Flume to 7500 bridge | 550[e] (25%) | 2230 |
| Melton Valley | | |
| HFIR/TRU | 5[f] | 3 |
| HRT/NSPP/MSRE | 70 | 56 |
| SWSA 4 | 700 (31%) | NA[g,h] |
| SWSA 5 | 540 (24%) | 320 |
| Pits and trenches | 50 | 26 |
| SWSA 6 | NA | NA |
| Total to White Oak Lake | 2250 | 3000 |

[a]Does not include underground pathways, if any, which might bypass the stream monitoring stations.
[b]Derived from data in Environmental Surveillance of the Oak Ridge Reservation and Surrounding Environs During 1985, ORNL-6271, April 1986, pp. 128, 129.
[c]Based on data in DEM files; personal communication from K. L. Daniels (ORNL) to M. B. Sears, June 23 and 26, 1986.
[d]Does not include 1982 which was 430 mCi.
[e]Does not include 1982 which was 790 mCi.
[f]Does not include 1983 which was 70 mCi.
[g]NA = Not available.
[h]In 1985 the input at the 7500 bridge station exceded the outflow at the White Oak Creek station. Therefore it is not possible to estimate SWSA 4 by the difference between these stations.

also high for several months from undefined Bethel Valley sources and the sewage treatment plant. There were no known line breaks during this period.[2] It was a wetter season than some in recent years, but 1979 was also a wet year and releases then were in the normal range. There were a number of construction projects in the early 80's in or near contaminated areas[2-4] which might have loosened contaminated dirt or allowed ingress of water into contaminated areas, followed by transport to the creeks. There will continue to be ongoing construction projects. For example, construction of the piping system for the proposed non-radiological wastewater treatment project may open up contaminated pipe trenches. Also the plant waste piping system is old and leaks are to be expected and with increasing frequency.

There is therefore an additional and unpredictable contribution from construction activities and waste line leaks/breaks or other unplanned events which should be added to the chronic releases. In 1985, the two unplanned events were the largest $^{90}Sr$ source at ORNL and caused the Laboratory to be in noncompliance.

### 4.1.2 Bethel Valley plant operations (controlled discharges)

The sanitary sewer system theoretically is a nonradioactive system, but in practice carries some activity. Potential sources of $^{90}Sr$ to the sanitary sewer system are water ingress from contaminated pipe trenches, leaking manholes, building floor or laboratory drains, and storm sewers from building areas carrying contaminated surface runoff.[2] Much of this system was relined in the summers of 1984 and 1985. However, 2000 feet in the most highly contaminated areas were not relined. The corrective measures were beneficial in reducing the volume of water ingress, but may not have much effect on the radioactive contamination.

The process waste treatment plant and the 190 ponds are relatively small $^{90}Sr$ sources.

### 4.1.3 Upstream of the flume (includes SWSA 2)

The monitoring station called "the flume" is located on White Oak Creek in the vicinity of the 190 ponds. (The effluent from these ponds is discharged below the flume.) The chronic $^{90}Sr$ discharge at the flume is about 6% of the total (Table 4.3). Fifth Creek, the isotopes area, Oak Ridge Research (ORR), 4500 area, transuranium research laboratory, and SWSA 2 lie upstream of the flume. There are 13 building drain pipes with a potential for contamination which empty directly to the creek. The pipe trenches in the isotopes area are highly contaminated.[2] The process waste line servicing the isotopes area runs along the creek bank with a relatively short distance to the creek.[2] Storm sewer and building drain pipe trenches which discharge to the creek potentially offer migration pathways from the process waste pipe trench to the creek.

The shallow groundwater drainage from SWSA 2 will drain to the flume. Ignoring vertical migration, if any, the flume station puts an upper limit on shallow groundwater discharges from SWSA 2. Most of SWSA 2 was exhumed and reburied in SWSA 3.[5]

### 4.1.4 Undefined sources between the flume and 7500 bridge stations

The undefined sources between the flume and the 7500 bridge station as summarized in Table 4.2 is the measured discharge at the 7500 bridge (the exit from Bethel Valley) minus the measured inputs from the flume, process waste treatment plant, and the 190 ponds. The undefined sources include the Northwest Tributary (SWSA 3) and First Creek (see Sect. 4.1.5). Potential sources include seepage from unlined ponds, leaking pipes and tanks, and contaminated pipe trenches, potentially contaminated building drains, surface runoff, a contaminated flood plain along the creek, SWSA 1, and SWSA 3.

### 4.1.5 SWSA 3 and First Creek

Stueber et al. found that the amount of $^{90}Sr$ discharged by the Northwest Tributary (including SWSA 3 and First Creek) averaged 6.4 mCi per month for the period September 1978 through May 1979.[6] This was a wet winter. Lomenick et al. reported a mean value of 6.6 mCi per month for a five month period in 1961.[6] More recently the Department of Environmental Management (DEM) monitored the Northwest Tributary (above the confluence with First Creek) and First Creek for the period July through November 1985, and found an average of 0.32 and 0.0014 mCi of $^{90}Sr$ per month respectively.[7] This was the dry season of a dry year. Cerling analyzed gravel samples collected at the seep on the Northwest Tributary and found that the $^{90}Sr$ activity in the summer of 1985 was about 30% of the level in 1978.[8] The lower levels in 1985 may not be of significance because of the dry weather. Conservatively assuming 6.4 mCi of $^{90}Sr$ per month (80 mCi/year), SWSA 3 would contribute 3.6% of the total chronic $^{90}Sr$ discharges.

The DEM monitored the Northwest Tributary and First Creek for concentration, but not for flow the first quarter of 1986. The concentrations in First Creek were higher the first quarter of 1986 than in the summer of 1985 (9-17 vs. 0.03-0.12 Bq/L). The concentrations in the Northwest Tributary were about the same in the winter (1.5-2.2) as in the summer (0.86-2.0 Bq/L).[7] It is not known whether the higher values in First Creek during the first quarter of 1986 are due to climatic factors or are a delayed effect of the filter pit spill near building 3517 in late November.

### 4.1.6 Melton Valley sources

As discussed earlier, SWSAs 4 and 5 are major sources of $^{90}Sr$, contributing 31% and 24% of the chronic releases. The measured surface drainages from the pits area are relatively small contributors - 2% of the chronic releases. This stretch of White Oak Creek is not monitored for seepage if any which by passes the weirs in the pit area.

The Homogeneous Reactor Test (HRT) waste pond, Nuclear Safety Pilot Plant (NSPP), and Molten Salt Reactor Experiment (MSRE) are small sources collectively contributing 3% of the chronic releases. The High Flux Isotope Reactor (HFIR) is a minor source (0.2%). The Transuranium Research Facility (TRU) releases only cooling water to the ponds (for subsequent discharge to Melton Branch).[9]

Quantitative data is not available for SWSA 6, which drains directly to White Oak Creek.

## 4.2 Tritium

The tritium discharges have been monitored at White Oak Dam for a number of years. Information about the sources is sparse. It is thought that most of the $^3H$ is coming from SWSA 5. Historically, $^3H$ releases were low until the mid 60's. Starting in 1967, a dramatic increase in the quantity of tritium was observed in the creek.[10] This increase was investigated, and the evidence indicated that the tritium originated in shipments of material received from Mound Laboratory prior to 1967.[10] The waste material was disposed of in SWSA 5.[10] Mound Laboratory did work on the hydrogen bomb and would have generated tritium bearing wastes.[11] There are reports that two shipments were received from "Site M" in Dayton (Mound Laboratory is near Dayton) in 1945 for burial followed by virtually weekly shipments from a source in that city during the late 40's."[12] This suggests the possibility of tritium in SWSA's 3 and 4. Tritium discharges at White Oak Dam remained high until about 1976 when they decreased to about the levels observed today (still relatively high).[13] SWSA 5 was closed to burials in 1973.[12] Corrective measures consisting of a new surface plastic membrane over four trenches and installing vertical dams in two trenches were completed in September 1975.[14]

The tritium discharges at White Oak Dam as a function of the precipitation are presented in Table 4.4 for the period 1976 to 1986. They have held constant with time at about 43 Ci/cm of precipitation.* Tritium has a half-life of 12 years. The inference is that the accessibility of the

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*The 1976 value may be a little high as the system may not have reached equilibrium after the 1975 corrective measures were applied to SWSA 5. If the 1976 data is deleted, the average is 42 Ci/cm of precipitation.

Table 4.4. Tritium releases at White Oak Dam as a function of the precipitation

| Year | Precipitation (cm) | $^3H$ Release | |
|---|---|---|---|
| | | Ci | Ci per cm precipitation |
| 1976 | 136[a] | 7420 | 54 |
| 1977 | 154[a] | 6250 | 41 |
| 1978 | 136[a] | 6290 | 46 |
| 1979 | 171[b] | 7700 | 45 |
| 1980 | 102[b] | 3400 | 33 |
| 1981 | 104[c] | 2900 | 28 |
| 1982 | 134[c] | 5400 | 44 |
| 1983 | 106[c] | 5600 | 53 |
| 1984 | 129[c] | 6400 | 50 |
| 1985 | 101[c] | 3700 | 37 |
| Average | | | 43 ($\pm$7) |

[a]ORNL steam plant data; V. T. Carmony (ORNL), personal communication to M. B. Sears, July 1, 1986.

[b]National Oceanic and Atmospheric Administration (NOAA) Oak Ridge weather station; B. Hicks, personal communication to M. B. Sears, June 4, 1986.

[c]Engineered Test Facility (SWSA 6) data; E. J. Davis (ORNL), personal communication to M. B. Sears, July 9, 1986.

waste to leaching is increasing at about the same rate as the tritium is decaying.

There is limited stream monitoring data for tritium at the White Oak Creek and Melton Branch 1 stations (Table 4.5). In 1972-1973 (before corrective measures), 90 to 95% of the tritium was found in Melton Branch. Duguid sampled 13 small seeps of SWSA 5 and found tritium at concentrations ranging from $2 \times 10^{-2}$ to $8 \times 10^{-1}$ uCi/ml all along the south side (Melton Branch drainage).[14] More recent monitoring by DEM, found that Melton Branch contributed 60% to 91% of the tritium in 1985 and the first quarter of 1986, respectively (Table 4.5).[7] However, there are anomalies in the 1985 data for the White Oak Creek station. An intermittent Bethel Valley source during the first half of 1985 is suspected. This might have been a delayed effect of the January process line break near building 3074 (i.e. a one-time release) or it might have been an intermittent operating release. Discharges at the White Oak Creek station for January to March 1986 were a factor of 10 lower than during the first quarter of 1985 although the precipitation was similar. In the first quarter of 1986, 91% of the tritium was from Melton Branch, 8 to 9% from SWSA 4, and 0 to 1% from Bethel Valley (near background). Upstream of SWSA 5 on Melton Branch are potential sources. The estimated tritium discharge from HFIR to the ponds (which discharge to Melton Branch) is about 31 Ci/year based on the analysis of the pool water and estimated flows*.[15] This is insignificant

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*Assumptions: Concentration of $^3H$ in HFIR storage pool water, $2.0 \times 10^{+6}$ Bq/L; discharge 10,000 gal. (38,000 L) per shutdown; 15 cycles per year.[15]

Table 4.5. Tritium discharge to streams[a]

| Period | $^3H$ Discharge (Ci) Melton Branch (SWSA 5) | White Oak Creek (SWSA 4 plus Bethel Valley) |
|---|---|---|
| 1972[b] | 9,540 (90%) | 1,060 |
| 1973[b] | 14,250 (95%) | 750 |
| 1985[c] | 2,570 (62%) | 1,560[d] |
| Jan-Mar 1986[c] | 1,400 (91%) | 120[e] |

[a]No discharge data for SWSA 6 or pits and trenches.
[b]J. W. Boyle, et al., Environmental Analysis of the Operation of the Oak Ridge National Laboratory (X-10 Site), ORNL-5870, November, 1982, p. 3-45.
[c]Based on data in DEM files; personal communication from K. L. Daniels (ORNL) to M. B. Sears, June 23, and 26, 1986.
[d]Anomalies in data; suspect intermittent Bethel Valley Source; $^3H$ releases during Jan. - Mar. 1985 were a factor of 10 higher than first quarter 1986 discharges.
[e]SWSA 4 contributed 8 to 9%; Bethel Valley contributed 0 to 1%.

compared with the 2,600 Ci discharged from Melton Branch in 1985. The TRU facility only discharges cooling tower water to the ponds.[9] TRU handles an estimated 12 Ci of tritium a year with the waste discharged to either the process waste system or the stack.[9] No information on tritium is available for the HRT pond seepage.

A summary of groundwater monitoring data for tritium around the SWSA's is presented in Tables 4.6 and 4.7 for 1984 and 1985. The presence of a contaminant in a monitoring well merely indicates a potential source. The creek contamination depends upon the rate of transport, which is unknown. The groundwater monitoring data shows that the $^3H$ levels are much higher in SWSA 5 than in the other burial grounds, and provides circumstantial evidence that there is a greater potential for $^3H$ releases from SWSA 5.

The SWSA's 1, 2, and 3 are probably minor $^3H$ sources since $^3H$ concentrations at the 7500 bridge station (exit from Bethel Valley) were only slightly above background during January to March 1986.[7]

Only quarterly grab samples of surface runoff taken during a dry year are available for SWSA 6.[16] The $^3H$ concentrations in the SWSA 6 drainage are relatively high ($8.2 \times 10^3$ to $1.4 \times 10^5$ Bq/L), but not much higher than the concentrations observed routinely in Melton Branch ($\sim 8 \times 10^4$ Bq/L), while the flow is much smaller. For the period June to October 1985, the sum of the measured flow at the SWSA 6 gauging stations was $1.0 \times 10^4$ $m^3$ compared with $5.7 \times 10^5$ $m^3$ at Melton Branch. This very sparse data indicates that in 1985, SWSA 6 was probably a relatively small contributor ($\sim$3%) to the total tritium discharges at White Oak Dam. However, SWSA 6 bears watching. It is not possible from the available data to predict seepage under normal precipitation conditions, the effect of containers corroding with time thus increasing the accessibility

Table 4.6. 1984 groundwater monitoring of radionuclides--ORNL[a]

| Analysis | No. of samples | Concentration ($10^{-8}$ uCi/mL)[b] Max | Min | Av |
|---|---|---|---|---|
| | | Solid Waste Storage Area 4 | | |
| $^{60}Co$ | 17 | 6.2 | <0.22 | <1.5 |
| $^{137}Cs$ | 26 | 270 | 0.76 | 32 |
| Gross alpha | 10 | 68 | 0.27 | 15 |
| $^{3}H$ | 24 | 170,000 | 590 | 28,000 |
| $^{90}Sr$ | 27 | 4,100 | 12 | 1,100 |
| | | Solid Waste Storage Area 5 | | |
| $^{60}Co$ | 33 | 6.5 | <0.19 | <1.1 |
| $^{137}Cs$ | 54 | 51 | <0.19 | <6.1 |
| Gross alpha | 24 | 25 | 0.27 | 4.6 |
| $^{3}H$ | 49 | 34,000,000 | 1,800 | 4,700,000 |
| $^{90}Sr$ | 50 | 220,000 | 0.49 | 5,500 |
| | | Solid Waste Storage Area 6 | | |
| $^{60}Co$ | 4 | 1.4 | <0.16 | <0.70 |
| $^{137}Cs$ | 9 | 23 | <0.54 | <10.0 |
| Gross alpha | 3 | 2.7 | 0.81 | 2.1 |
| $^{3}H$ | 11 | 3,900 | <81 | <1,300 |
| $^{90}Sr$ | 12 | 470 | 1.9 | 140 |
| | | Pits and Trenches | | |
| $^{60}Co$ | 36 | 2,600 | 0.41 | 410 |
| $^{137}Cs$ | 36 | 130 | 0.57 | 16 |
| Gross alpha | 15 | 410 | 0.27 | 62 |
| $^{3}H$ | 34 | 25,000 | 570 | 10,000 |
| $^{90}Sr$ | 35 | 230 | 0.43 | 29 |
| | | Reference Wells | | |
| $^{60}Co$ | 3 | 1.4 | <0.08 | <0.58 |
| $^{137}Cs$ | 7 | 12 | <1.0 | <5.0 |
| Gross alpha | 2 | 2.7 | 2.2 | 2.4 |
| $^{3}H$ | 10 | 360 | <81 | <220 |
| $^{90}Sr$ | 10 | 35 | 1.0 | 13 |

[a]Environmental Monitoring Report United States Department of Energy Oak Ridge Facilities, Calender year 1984, ORNL-6209, August 1985, p. 71.
[b]To convert from $10^{-8}$ uCi/mL to $10^{-4}$ Bq/mL multiply value in table by 3.7.

Table 4.7. 1985 groundwater monitoring of radionuclides around ORNL solid waste storage areas[a]

| Analysis | No. of samples | Concentration ($10^{-8}$ uCi/mL)[b] Max | Min | Av |
|---|---|---|---|---|
| | | **Solid Waste Storage Area 4** | | |
| $^{60}Co$ | 8 | 0.54 | <0.27 | <0.49 |
| $^{137}Cs$ | 8 | 2.3 | <0.27 | <0.82 |
| Gross alpha | 8 | 170 | 2.7 | 32 |
| $^{3}H$ | 8 | 200,000 | 1,100 | 34,000 |
| $^{90}Sr$ | 8 | 2,500 | 30 | 660 |
| | | **Solid Waste Storage Area 5** | | |
| $^{60}Co$ | 11 | 3.0 | <0.27 | <0.80 |
| $^{137}Cs$ | 11 | 2.7 | <0.27 | <0.97 |
| Gross alpha | 11 | 95 | <1.1 | <21 |
| $^{3}H$ | 11 | 7,300,000 | 2,000 | 2,000,000 |
| $^{90}Sr$ | 11 | 1,400 | 1.8 | 480 |
| | | **Solid Waste Storage Area 6** | | |
| $^{60}Co$ | 6 | 0.54 | <0.27 | <0.50 |
| $^{137}Cs$ | 6 | 1.6 | <0.27 | <0.58 |
| Gross alpha | 6 | 5.4 | <1.4 | <3.7 |
| $^{3}H$ | 6 | 6,200 | 190 | 2,100 |
| $^{90}Sr$ | 6 | 8.4 | 0.35 | 2.3 |
| | | **Pits and Trenches** | | |
| $^{60}Co$ | 8 | 2,000 | <0.54 | <580 |
| $^{137}Cs$ | 8 | 3.2 | <0.27 | <1.8 |
| Gross alpha | 8 | 130 | 0.54 | 33 |
| $^{3}H$ | 8 | 14,000 | 2,200 | 8,600 |
| $^{90}Sr$ | 8 | 12 | 0.22 | 3.2 |
| | | **Reference Wells** | | |
| $^{60}Co$ | 4 | 0.54 | <0.54 | <0.54 |
| $^{137}Cs$ | 4 | 1.1 | <0.27 | <0.58 |
| Gross alpha | 4 | 6.2 | 1.6 | 3.5 |
| $^{3}H$ | 4 | 250 | 120 | 170 |
| $^{90}Sr$ | 4 | 3.2 | 0.19 | 1.4 |

[a]Environmental Surveillance of the Oak Ridge Reservation and Surrounding Environs During 1985, ORNL-6271, April 1986, p. 168.
[b]To convert from $10^{-8}$ uCi/mL to $10^{-4}$Bq/mL multiply value in table by 3.7.

of the waste to leaching, or the underground migration, if any, direct to White Oak Lake, bypassing the weirs.

No data is available on $^3H$ discharges from the pits area. The ground water monitoring data suggests that the pits and trenches are probably small contributors compared with SWSA 5, but stream data is needed for confirmation.

In summary, $^3H$ is the major contributor to the drinking water total body dose. For planning purposes the conservative approach would be to assume 90% of the tritium from SWSA 5, 10% from SWSA 4, and watch both SWSA 6 and Bethel Valley sources. It is recommended that additional monitoring data for $^3H$ be acquired.

## 4.3 Cesium-137 and Cobalt-60

Discharges of $^{137}Cs$ and $^{60}Co$ from several sources to the White Oak Creek drainage in 1985 are presented in Table 4.8. Some caution should be exercised in using this information because there may be other sources which were not monitored and other uncertainties. Both longer term monitoring and more sampling points are needed to draw a material balance.

Of the known sources, the process waste treatment plant is the major source of $^{137}Cs$ in agreement with Cerling's studies of the gravels in the creeks.[8]

There was a large $^{60}Co$ spike at White Oak Dam week 9 - 375 mCi or 60% of the total 1985 discharge. The Melton Branch discharge week 9 was only 1 mCi. Data were not available for week 9 at the White Oak Creek station but the monthly composite was 31 mCi. Precipitation was low that week [1.9 mm at the Engineered Test Facility (SWSA 6)[16]], so there were

Table 4.8. Discharges of $^{137}Cs$ and $^{60}Co$ from various waste areas to White Oak Creek drainage in 1985[a]

| Area | Discharge (Ci) | |
|---|---|---|
| | $^{137}Cs$ | $^{60}Co$ |
| Bethel Valley | | |
| Process waste treatment plant | 1090 | 240 |
| Sewage treatment plant | 5 | 2 |
| 190 Ponds | 14 | 3 |
| Undefined sources | NA[b] | NA |
| White Oak Creek (Bethel Valley & SWSA 4) | 1110 | 210 |
| Melton Branch | 6 | 140 |
| Pits and trenches | NA | NA |
| SWSA 6 | NA | NA |
| White Oak Dam | 1110 | 630[c] |

[a]Based on data in DEM files; personal communication from K. L. Daniels (ORNL) to M. B. Sears, June 23 and 26, 1986.

[b]NA = not available.

[c]Uncertainty in this value; see discussion in Sect. 4.3.

no storms to transport contaminated sediments. There is therefore considerable uncertainty in the $^{60}Co$ discharge at White Oak Dam and the value in Table 4.8 may be in error. Of the known inputs to White Oak Lake, the process waste treatment plant contributed about 60% and Melton Branch sources 40% of the $^{60}Co$ in 1985. Cerling's studies of the creek gravels indicate that the HFIR/TRU area is the source of most of the $^{60}Co$ in Melton Branch.[8]

The low concentrations of $^{137}Cs$ and $^{60}Co$ in the groundwater around SWSAs 4, 5, and 6 indicate that these are probably overall minor sources, although an individual seep may require consideration (Tables 4.6 and 4.7).

The heaviest 24-hour precipitation of the year occurred August 16 - 101 mm at the Engineered Test Facility station (SWSA 6) followed by 38 mm the following day. The known inputs to White Oak Lake exceeded the outflow at the dam, that is White Oak Lake functioned as a settling basin (Table 4.9). For this particular storm White Oak Lake itself did not appear to be an active source, when compared with other sources in the watershed. However, the 30 year accumulation of contaminated sediments in White Oak Lake is an important potential source which should be addressed in the decommissioning plan.

Table 4.9. Discharges of $^{137}Cs$ and $^{60}Co$ during August 1985 storm[a]

| | Discharge (mCi) | | | |
|---|---|---|---|---|
| | $^{137}Cs$ | | $^{60}Co$ | |
| Area | Week 33[a] | Week 34[b] | Week 33 | Week 34 |
| White Oak Creek | 10.8 | 70.5 | 3.0 | 8.5 |
| Melton Branch | 0.8 | 0.4 | 10.7 | 6.7 |
| Sum (known input to White Oak Lake) | 11.6 | 70.9 | 13.7 | 15.2 |
| White Oak Dam | 2.9 | 13.7 | 3.6 | 4.8 |

[a]Based on data in DEM files; personal communication from K. L. Daniels (ORNL) to M. B. Sears, June 23 and 26, 1986.

[b]Storm occurred week 33.

[c]Stream flow peaked at White Oak Dam week 34.

## 4.4 References


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## 5. EVALUATION AND RECOMMENDATIONS

A search was made for information which could be used to develop source terms for the dose calculations by waste management sites or areas. Some data was found for $^{90}Sr$, although it is primarily by area rather than for individual sites. Quantitative source term data has not been found for $^{3}H$, $^{137}Cs$, or $^{60}Co$. Additional source term data is needed before the dose calculations by individual sites can be made.

A qualitative assessment was made based on the available information for preliminary planning purposes. The waste management areas were evaluated in terms of currently active discharges of environmentally significant nuclides to surface streams. Of the discharges which are known, the central Bethel Valley site, SWSA 5, SWSA 4, and the process waste treatment plant offer the greatest potential for dose reduction (near term) if corrective measures are applied (Table 5.1). The SWSA 6 bears watching. While this appeared to be a small source in 1985, discharges might be higher under normal precipitation conditions. Also since it is the most recent burial ground, leaching might increase with time. The SWSAs 2 and 3, the HRT ponds, the HFIR ponds and the TRU ponds are lower priority from the perspective of off-site dose to the general public. The limited data available indicates that White Oak Lake is probably not contributing much to off-site discharges compared with other sources in the watershed. However the accumulated sediments are an important potential source which should be addressed in the decommissioning plan.

At the present time, releases of TRU alpha emitters from ORNL are quite small. The plutonium content of Clinch River fish is highest near the confluence with Poplar Creek (Table 3.5) and the source is probably the Y-12 plant. From the long-range perspective it is important to establish that the long-lived TRU alpha emitters are not migrating and will be permanently confined in the burial grounds.

Additional monitoring data should be acquired, for both surface water transport and ground water migration.

Table 5.1 Priority Areas for Remedial Investigation

| Ranking | Waste management area | Criteria[a] | Objective of remedial action |
|---|---|---|---|
| 1a | Central Bethel Valley site Unidentified sources | Contribute ~27-31% of chronic $^{90}Sr$ discharges (~30 mrem bone dose from drinking water) | Reduce bone dose |
| | Construction activities, line breaks, etc. | In 1985 increased Bethel Valley site discharges a factor of 3 and caused ORNL to be in noncompliance | Ensure regulatory compliance; ALARA |
| 1b | SWSA 5 | Contributes ~60-90% of $^{3}H$ and ~24% of the $^{90}Sr$ (~22-31 mrem total body and ~39-46 mrem bone dose from drinking water) | Reduce drinking water total body dose; reduce bone dose |
| 2a | SWSA 4 | Contributes ~31% of $^{90}Sr$ and ~10% of $^{3}H$ (~7 mrem total body and ~35 mrem bone dose from drinking water) | Reduce bone dose |
| 2b | Process waste treatment plant | Contributes most of $^{137}Cs$ and about half the $^{60}Co$ | Reduce total body dose from eating Clinch River fish |

[a]Dose estimates are for drinking the water at White Oak Dam and assume the 1984 discharges and distribution factors defined above.

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